Growth of structured anisotropic deposits on plasma facing surfaces in fusion devices

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Modification of plasma facing surfaces (PFC) of magnetic confinement fusion devices under heat and particle impact may lead to limitation of the components life time and/or accumulation of excessive amounts of tritium. We analyze sampled wall materials from two fusion devices with different topology and magnitude of magnetic field at the edge and different composition of the first wall. Samples from the divertor of JET tokamak were collected in the strike point region after last experimental campaign with C wall. They exhibit structured, highly ordered deposits with the layer thickness about 30 μm. The material is mainly carbon with co-deposited D and inclusions of Be and Ni also in form of droplets. On the micro scale the deposits have columnar structure with column diameter d ranging from few μm down to nm and length exceeding 10d. The columns are strongly anisotropic and their toroidal inclination favours the direction of diffusive ion flow towards the divertor target. Nevertheless, in poloidal projection the columns grow towards the divertor.

Samples of loose material were also taken from the inner wall of T2R reversed field pinch after 10 years of operation with a full metal wall. Collected material mostly consists of spherical metallic dust particles rich with stainless steel components and Mo, which are the only materials of plasma facing components in T2R. SEM and FIB SEM analysis of the particles showed that all of them have a stainless steel core, covered by a mixed layer rich with Mo and containing SS. Thickness of deposited layers on individual grains is non uniform and reaches at most few 100 nm. The layers can grow asymmetrically on individual grains suggesting both anisotropy of the deposition flow and that the particles have been immobile on the wall during many discharges. Orientation of the particles has been controlled throughout collection and analysis what allowed to conclude that the metal layer growth favours on average the direction towards the local diffusive flow.

In order to explain observed asymmetries of the structure growth we model particle trajectories starting from the entrance to the magnetic pre-sheath region in front of the surface. We show that due to finite Larmor radius, particles impact angle is restricted. The range of impact angles weakly depends on local plasma parameters. Morphological differences between deposits in both cases can be explained by the constitution of the deposition fluxes.